Coding in the Evolution of Signalling Behavior

By

THOMAS A. SEBEOK

Indiana University

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This paper examines two of the differences between human speech and communication in subhuman species: (1) the different types of information that each species can communicate, and (2) the different methods by which they code information.

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SPEECH communication may be studied as an information system, and natural language as the code used in the system (Jakobson, 1961; Plath, 1961; von Weizsäcker, 1959). From this point of view it seems useful, on the one hand, to investigate the analog and digital characteristics of human communication and, on the other, to compare human and animal communication systems as to the manner in which they code information.[1]

DIGITAL AND ANALOG CODING

Communication engineers often distinguish between two kinds of control machines: those for counting and those for measuring. The former, which are all-or-none devices, are sometimes called digital; they are of a "yes-or-no" type. The latter, which operate on the basis of connections between measured quantities and the quantities they represent, are, by contrast, known as analog; they are of a "more-or-less" type. The prototype of a digital system is the abacus, that of the analog the slide rule; in the realm of biology, our heartbeat may be said to illustrate the former, and our capillary flow the latter, type of process. The chief limitation of analog systems relates to their accuracy; on the other hand, those physical systems which are able to make yes-or-no decisions can achieve any desired precision, given sufficient capacity and time.

A further observation is that the functioning of the nervous system is *prima facie* digital: "if a combination of incoming messages will not cause an outgoing fiber to fire, it is said to be *below threshold;* otherwise, it is said to be *above threshold*" (Wiener, 1950, p. 74). Nervous pulses can thus be viewed as two-valued markers: the presence of a pulse (release of acetylcholine?) above threshold represents one value, say, the binary digit 1, and the absence of a pulse (release of cholinesterase?) another, say, the binary digit 0. That the brain is not, however, merely a glorified digital machine but a mechanism built upon a more primitive analog basis, and that the processes which pass through the nervous system may repeatedly change their character from digital to analog and back to digital, was set forth in a posthumous book by J. von Neumann (1958, pp. 68-69): "Nerve pulses, i.e., the digital part of the mechanism, may control a particular stage of such a process, e.g. the contraction of a specific muscle or the secretion of a specific chemical. The phenomenon is one belonging to the analog class, but it may be the origin of a train of nerve impulses which are due to its being sensed by suitable inner-receptors. When such nerve pulses are being generated, we are back in the digital line of progression again . . . such changes from a digital process to an analog one, and back again to a digital one, may alternate several times. Thus the nerve-pulse part of the system, which is digital, and the one involving chemical changes or mechanical dislocations due to muscular contractions, which is of the analog type, may, by alternating with each other, give any particular process a mixed character."[2]

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[1] An early draft of this paper was prepared for and discussed in a symposium on "Comparative Aspects of Human Communication," held under the auspices of the Wenner-Gren Foundation for Anthropological Research, at Burg Wartenstein, Austria, September 4 to 10, 1960. Another version was completed during the author's residence as a Fellow at the Center for Advanced Study in the Behavioral Sciences; was further modified in January, 1962; and will also appear, in a somewhat different form, as a chapter in P. L. Garvin (Ed.), *Natural Language and the Computer,* New York: McGraw-Hill, 1963. The opportunities afforded by the Foundation and the Center are gratefully acknowledged.

The decisive property of a digital organ or mechanism, then, is that it is almost always found in one or another of its two extreme discrete states, i.e., that the dynamic probability of its standing in the intermediate state which forms the connecting continuum is very small. It thus appears that the phenomena called digital are, in reality, also continuous although largely indifferent to subliminal variations of the input stimuli. One treats such phenomena by ignoring the transition states, that is to say, by assuming that information is being conveyed in a binary code.[3] (By coding is meant an operation, governed by strict and logical rules, aimed at gaining increased efficiency by having elementary signals organized into patterns of alternative actions; by code is meant everything that the source and the receiver know *a priori* about the message.)

Whatever the exact situation may be in the central nervous system—a problem which Gerard (1951, 1959), among others, has impressively elucidated—the model sketched above has certainly proved of heuristic value, even though some may feel that the digital procedure is a human artifact invented for the sake of description, and that the underlying reality is truly analog. Gerard pictures the nervous system as "made up of relatively uniform units, which can be combined in various ways, rather than of highly particularized units, each one of which stands for something specific." The proof of this lies in the existence of synapses which are, in effect, foci of decision. This model can then be extended to encompass speech; as DuBrul (1958, p. 90) recently put it: "Speech is the spark that spans the synapse between two nervous systems." (The notion of a theoretical continuity between the nervous system and the linguistic system is elaborated in Shands [1960].)

This paper has as its theme the hypothesis that whereas subhuman species communicate by signs that appear to be most often coded analogly, in speech (contrary to the opinion of certain linguists) some information is coded analogly and other information is coded digitally. The digital mechanism of speech may, therefore, be regarded as a late development in the phylogenetic series and perhaps a uniquely human faculty. (It is not, of course, our contention that the differential use of these two types of mechanisms is the *only* mark that sets off speech from communicative behavior via other modalities and in other species. C. F. Hockett, for example, has identified seven [1959]—later thirteen [1960a, 1960b]—"universal" properties of language, with a surprisingly broad area of overlap, and even this list is doubtless not exhaustive.[4])

To elaborate somewhat crudely in the neurological domain: in speech, emotions may be codified in analog terms, in which case neocortical as well as limbic or neurohumoral areas are simultaneously involved; other, i.e., "rational" aspects of existence are codified in digital terms, presumably involving centrencephalic integration only (Ruesch, 1955).[5] In his re-examination of von Frisch's classic studies of bee "language" (1950),[6] Kroeber (1952) similarly distinguished between signs and symbols, according to their respective functions (emotive vs. cognitive). His study leaves the door open to the possibility that certain subhuman species, notably the social insects, may partially communicate by systems of symbols, but the evidence for this is far from persuasive. (In a discussion shortly before his death, Kroeber observed to the author that he no longer held the view expressed in his paper cited.)[7]

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[2] "It may be pointed out that on fuller investigation the nervous impulse turns out to be not fully digital in its behaviour. But then, even the digital elements of an 'electronic brain,' the relay and the valve, are ultimately made up of continuous-operator elements put together in such a way as to exhibit digital functioning. The electromagnetic relay, the thermionic valve and the nerve cell are, in fact, complex mechanisms which under certain specific operating conditions function as digital units" (Sluckin, 1960, pp. 127-128). On the relation between the two techniques in general, see the classic exposition by Mackay (1959) but also the terminological strictures of Elias (1961).

[3] The proposition of Weinberg (1951), "that the living organism resorts to the method affording ultimate efficiency and economy, which is, in the case of elements for coding information, ternary rather than binary," presents another, but needlessly complicated, model where the signal may take the forms: + stimulate, — inhibit, and 0, no effect.

[4] Thus one might add a property of "multiple coding potential," that is, the possibility that language is the only communicative system permitting the transmutation of one set of verbal signs (e.g., speech) into another set (e.g., script). A view is also maintained that no single attribute of language is unique to man but that this is, on the contrary, distinguished unequivocally from communicative systems in other species merely by virtue of the particular combination of characteristics—a complex form of encoding which has evolved to meet the needs of human communication (see Koehler, 1956).

COMMUNICATION CHANNELS

Speech is the principal, but by no means the only, mechanism whereby communities are knit into social organizations via a systematic flow of messages exchanged over interpersonal communication channels. These channels are made up of a number of different bands over which messages can move synchronously. There is a vocal-auditory band which couples movements of vocal muscles with stimulation of auditory receptors. There is also a gestural-visual band which couples movements of facial and body muscles with stimulation of visual receptors. Interpersonal messages in everyday communication travel simultaneously over these auditory and visual avenues, typically reinforcing one another but occasionally conflicting in certain situations.[8] Other sensory modalities (such as touch, [Frank, 1957; Geldard, 1960; Gilmer & Gregg, 1961] smell, taste, and temperature) may participate in communication—they certainly do with other species (Haldane, 1955; Marler, 1959), and the remarkable feats of Helen Keller show that they can be highly discriminating even in the human—but they usually contribute in limited and unintentional ways, since they are seldom under voluntary control. There is, finally, what might be called the manipulational-situational band which, by the mediation of "things" manipulated and observed, couples source and destination (Goffman, 1959; Hall, 1959; Hayes, 1957; Osgood & Sebeok, 1954; Ruesch & Kees, 1956).

The variety of communication channels deserves further illustration and emphasis. Thus, Tinbergen has convincingly shown that gulls communicate with one another by means not only of calls but also postures and movements; and L. T. Evans (1955, p. 274), speaking of *Crocodilia,* reported: "When the mature male American alligator roars, his middle section lies about 2 inches beneath the surface of the water. The terrific reverberation of the bellow . . . is such as to send up a fountain of water above his body. The combined effect of the roar, the musky odor emitted from the glands at the corners of his jaw, as well as the fountain, serve to attract the female and perhaps to repel a rival male."[9]

The most general model of a communication network postulates that one system, a source, influences another system, a destination, by dispatching alternative signals that are carried in the channel connecting them. The information source is conceived as producing one or more messages which must be transformed, or encoded, by a transmitter into signals which the channel has the capacity to carry; these signals must finally be transformed, or decoded, by a receiver back into messages which can be accepted by the destination (Fano, 1961; Shannon & Weaver, 1949). This model of the communication process, developed in connection with engineering problems, was not intended as a blueprint of human communication. For one thing, it implies normal separation of source and destination, of transmitter and receiver, whereas the individual human functions more or less simultaneously as both—indeed, he regularly decodes through various homeostatic mechanisms the messages he himself has encoded.

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[5] The parts of dominant cortex and thalamus that are devoted to the learning of speech and its uses are delineated in Penfield and Roberts (1959). On "rational" and "emotional" speech in pathology, and a survey of the philosophical "idea that outcries of emotion represent the basis of all language," see Goldstein (1948, Ch. 4).

[6] The latest research results on this subject are brought together in Lindauer (1961) and von Frisch (1962).

[7] For another relevant discussion of "the difference between sign behavior, which is prelinguistic intelligent behavior, and linguistic behavior, which is behavior mediated by the symbol system we call language," see Greenberg (1959). Several linguists have analyzed human speech in contrast to bee communication: e.g., Laziczius (1942, p. 31), Lotz (1950, 1951), and Benveniste (1952).

[8] A striking illustration of within-band contradiction was pictured in *Life*, 48, 9, 106-122, 1960. A patient was told under hypnosis she must raise her right index finger to indicate an affirmative answer, left for negative. Brought out of trance, she was questioned by her doctor. Unable to face her emotional problem, she shook her head vigorously in manifest negation, but her right finger shot up, showing that the correct answer was "yes." For a general clinical assessment of normal and pathological communicative behavior, see Ruesch (1957).

[9] Speaking earlier at the same conference, Margaret Mead identified as the gifted individual that person "who has had the luck to have had all . . . possible modalities stimulated. If you analyze communication, the person who gets over the greatest communication to the group is the person who uses several sensory modalities" (1955a, p. 241).

Insofar as the messages which are being interchanged belong to speech, they constitute the traditional preoccupation of linguists. Other partially or wholly verbal messages may include myths, the various aspects of ritual, marriage rules and kinship systems, customary law, certain modalities of economic exchange, and the like; these form the subject matter of social anthropology in general, as well as of such special disciplines as law or economics or folklore in particular (Lévi-Strauss, 1960).

An information-theoretical model

In a widely influential model, especially as developed by Bühler (1934), the act of speech was confined to three aspects: those features of sound which are characteristic of (I) the source (*Kundgabe*, the first person of the addresser), those which constitute (II) an appeal to the destination (*Appell*, the second person of the addressee), and those which refer (III) to the designation (*Darstellung*, the so-called third person—someone or something spoken of). It would seem useful now to expand this triadic model into a hexagonal one, which involves the following dimensions: (I) an addresser (or actor) who selects—i.e., encodes according to specific statistical constraints—(V) a message out of (VI) a code

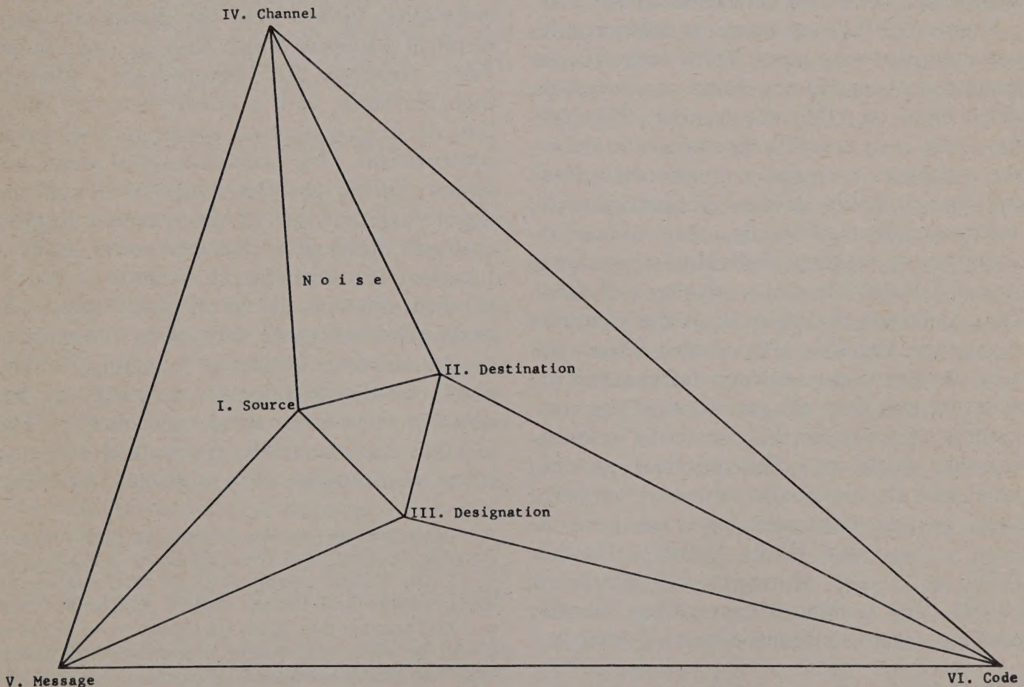

FIG. 1. A Morley Triangle Showing the Relation Between Bühler's Model and an Information-Theoretical Model of a Communication Network. Morley's theorem illustrates the relation between Bühler's model (the small equilateral triangle) and a more comprehensive information-theoretical model of a communication network. The encoder and decoder are often the same individual.

which must be—to permit decoding—fully or at least partially shared by (II) an addressee (or reactor); the message also requires (III) a referent (or, better, context) and (IV) a "channel" allowing the participants to establish and maintain contact. (That portion of a communication which intrudes into the message en route from source to receiver is noise; it is mixed intimately, although in varying proportions, with the signal—that portion of a communication which originates with the addresser.)

The relation between Bühler's model and an information theoretical model of a communication network may be illustrated by a Morley triangle (Fig. 1).[10]

These six factors determine the hierarchical order of linguistic functions, and the verbal structure of any particular message depends on the function which predominates. Although orientation toward the referent—the so-called denotative, cognitive, or referential function —is the principal burden of many messages, the other five accessory functions are ever-present and must also be accounted for.

Kroeber (1952) comments as follows on his distinction between signs, which focus (in our terminology) on (I) the source, and symbols, which focus on (III) the context: "In function, signs that serve to communicate are action responses to sensory or visceral stimuli and are probably always accompanied by emotional affects. Directly, they convey information to recipient individuals only as to the condition of the sign-producing individual. They alert one organism as to the condition of another, which is often useful. True symbols, however, can convey information on other matters than the condition of the communicating organism. Such external information may fairly be called objective, as compared with the essentially subjective nature of what is communicated by non-symbolic signs." (See also White [1940], Cassirer [1944, pp. 31-32], Morris [1946], and Frank [1960]. The notion of context has recently been elaborated by Slama-Cazacu [1961].)

THE SIX COMMUNICATIVE FUNCTIONS

This dyadic model of sign/symbol certainly represents an overly simplified picture of what happens in speech, and probably in some forms of animal communication as well; it fails to accommodate at least four functions other than the emotive and cognitive. One of these was observed and described by B. Malinowski, who named it "*phatic communion . . .* a type of speech in which ties of union are created by a mere exchange . . ." (Malinowski, 1923, p. 315). Such messages which serve primarily to establish, prolong, or discontinue communication, to check whether (IV) the channel works in good order, occur not only in human discourse—cf. this legend on a greeting card: "This Card Serves No Useful Purpose—except to make money for the manufacturer and to assist me in communicating with you and sustaining our relationship"—but also among frogs and certain birds, e.g., the sparrows and the psittacines (bird to bird as well as bird to human).[11] In speech, orientation toward (II) the destination may result in sentences which have no truth value (viz., vocatives and imperatives); whether such messages, with a chiefly conative function, occur in subhuman species as well seems controversial. (For one summary of views, see Kainz [1943, pp. 220-224].) Perhaps the deictic "chink" call of the common English chaffinch (*Fringilla coelebs*) serves such a function: if a bird of prey, such as an owl, is perched prominently in a tree, "the small birds will often make themselves conspicuous too by behavior known as 'mobbing'." They point out the predator, so to speak, by addressing themselves to all and sundry. The jackdaw has two calls, transcribed *Kia* and *Kiaw,* said to mean "Fly with me!" by which the bird beckons others in the flock.[12] In any case, encoder and decoder are often the same individual—like a blind man tapping with his cane—as witnessed for instance by the manner in which electric fish distort their own high-voltage fields; by the striking aerodynamic sonar system in *Chiroptera;* and by the even more sophisticated sonar system in cetaceans (Griffin, 1958; Kellogg, 1961; Lilly, 1961). The fifth set, which aims toward (V) the message as such, is the poetic function of language, as has been illuminatingly discussed in this framework by Jakobson (1960);[13] and the last one, which focuses on (VI) the code, and which permits the rewording or translation of a linguistic sign into some further, alternative sign, is usually called its glossing function (Cherry, 1957, Ch. 3, Sec. 2; Jakobson, 1959).

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[10] On Morley's theorem, which asserts that when the three angles of a triangle of any shape are trisected, the trisecting lines always meet at the vertices of an equilateral triangle, see Coxeter (1961).

[11] The message on the greeting card was reproduced in the *New York Times Magazine*, April 3, 1960, p. 53. On "phatic communion" in other species, cf. Kainz (1943) and Révész (1956). Jakobson (1960, p. 356), commenting upon the endeavor of "talking birds" to start and sustain communication, asserts that "the phatic function of language is the only one they share with human beings," and adds that it is also "the first verbal function acquired by infants . . . ." On the imitation of speech by birds, see, for example, an account by de Haan (1929).

To summarize, of the six communicative functions, two—the emotive and the phatic—certainly occur in subhuman species as well; two others—the cognitive and the conative—probably occur; but the remaining two—the poetic and the metalingual—seem to be exclusively human. (For an overview of the acoustic aspects only, cf. Collias [1960], Marler [1959], and Haskell [1961].)

CODING OF EMOTION

In the trenchant formulation of Stankiewicz, a human being may speak or may remain silent. If he does decide to speak, he has a freedom of choice in regard to the message to be transmitted. However, as to the code, his freedom is restricted: his selection must be made out of "prefabricated units" among sets of simultaneous binary distinctions (Halle, 1957),[14] elements in an algorithm (or decision procedure) concatenated into sequential patterns. According to this selection, he varies the cognitive content, or meaning, of his messages. But, keeping the meaning constant, the speaker is also free to flavor and color his message in a variety of ways. This possibility of modulating his attitude toward what he speaks about is the pragmatic dimension of "emotion." Here, again, the speaker has at his disposal features which are strictly conventional; but he is not necessarily forced to make binary or ternary choices, for by even a barely perceptible variation in the degree of the quality of such devices he can mirror a range of differences in his emotional intensity (associated, presumably, with a rising production of hormones).

A bird may likewise vocalize or remain silent and may, moreover, have a certain choice in regard to the message to be transmitted: thus the common whitethroat (*Sylvia communis*) has been found to have twenty-four innate sounds. Crows have been reported to possess four or more distinct cries, two of which can be identified and have been labeled, respectively, the assembly call and the dispersal call. Furthermore, it has been shown that the crows' reactions to the calls are only partly inborn; in part they seem to be the result of copying from other individuals. But once the contact has been established, the number of caws emitted will vary from one to five, their frequency being in direct proportion to the degree of excitement (Sauer, 1954; H. Frings & M. Frings, 1959). There exist, of course, other types of communicative situations where a frequency-intensity relationship may prevail such that even rather substantial changes in the frequency of a response are accompanied by only very small formal modifications, thus resulting in reduction of signal ambiguity. The difference may be summed up by this analogy: the harder a cyclist pedals, the faster his vehicle moves; but a telephone rings at a constant rate regardless of the urgency of the call (although it may ring commensurably longer) (Morris, 1957).

A human being may speak or may remain silent: the speech signal (like acoustic signals in general) is transient—that is, it can be altered rapidly and turned off entirely. This property is not necessarily shared, however, by communication in other modalities—for instance, the olfactory. Thus a skunk is able to emit a chemical signal very abruptly, but lacks the capability to shut it off: the message persists interminably, even in the sender's absence. Communication by smell therefore functions, in this and other respects—including especially the capacity for delayed feedback—like writing rather than like speech.

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[12] On the chaffinch, see Thorpe (1956); on the jackdaw, Lorenz (1952); more generally, Marler (1957) and Thorpe (1961).

[13] I am indebted to this essay for a formulation of the hexagonal model of language.

[14] On the principle of dichotomy, viewed in philosophical perspective, see Ogden (1932).

The symbolic information-bearing sound features of speech include the distinctive and configurative (or constructive). There are linguists who are convinced that all utterances can be dissolved into and characterized by sets of two-valued attributes (Jakobson & Halle, 1956), while other linguists prefer to have recourse to more complex principles of patterning (Martinet, 1957-1958), but all agree that the coding of such features is digital. When, however, it comes to other information we know is carried in the vocal-auditory band, the nature of the coding is far less clear.

Expressive features of language

Charles Darwin was one of the first (he himself cited Herbert Spencer's essay on "The Origin and Function of Music" in this context) to explore in methodical detail, as well as to provide with an evolutionary interpretation, what he called *The Expression of the Emotions in Man and Animals* (1872).[15] In the fourth chapter, where he takes up specifically "a very obscure subject," the emission of sounds, he remarks pessimistically: "It is not probable that any precise explanation of the cause or source of each particular sound, under different states of mind, will ever be given." Half a century later, Sapir (1927) echoed Darwin's observation: "The voice is a complicated bundle of reactions and, so far as the writer knows, no one has succeeded in giving a comprehensive account of what the voice is and what changes it may undergo. There seems to be no book or essay that classifies the many different types of voice, nor is there a nomenclature that is capable of doing justice to the bewildering range of voice phenomena." And over a quarter of a century still later, Jakobson and Halle (1956, p. 11) are obliged to repeat that the systematic study of such "physiognomic indices," as they prefer to call them here, "still remains on the agenda."[16]

Linguists like Bally, Devoto, Spitzer, von Wartburg, Vossler, and others who insist—again to paraphrase Stankiewicz—on emphasizing the priority and esthetic superiority of the message over the code, have actually paid attention to aspects of the expressive language problem. But in structural linguistics, the expressive range of morphophonemic, morphological, and syntactic considerations—to say nothing of code-switching between a neutral and an emphatic style, between one social dialect and another—has been virtually ignored. Only on the phonemic level have a few structuralists touched on the notion of expressiveness, most originally among them Laziczius who was the first to insist on the conventional nature of the elements he designated "emphatics."[17] Trubetzkoy (1939) was of the opinion that data in this area are so meager and unreliable that one could but speculate about their role in language, and he ended by relegating them to a special branch of phonology which he wanted to be designated *phonologische Stilistik*. Only during the last few years have linguists and psychologists alike begun attempts to disentangle afresh the interwoven threads of the total ribbon of speech. We owe to Lotz (1950, 1954) the most comprehensive—if excessively laconic—typology of features, which encompass invariants that are either socially determined or bound by the somatic characteristics of our organs and by our habits of speech, in addition to the variable pragmatic features said to be "continuous in the sense that a variation in the emotional expression indicates a difference in the intensity of the emotion, the louder one shouts, the angrier the impression one creates." Socially determined features include the so-called vocalizations—vocal characterizers, qualifiers, and segregates—first specified by H. L. Smith, Jr. (1952; Pittenger & Smith, 1957) and then applied as a psychotherapeutic tool by some of his collaborators (McQuown, 1957; Pittenger, 1958).[18] Another categorization entirely—in terms of a series of dichotomous distinctions between learned vs. unlearned, voluntary vs. involuntary, and constant vs. intermittent features—has been suggested by a team of linguists and psychologists (Osgood & Sebeok, 1954, p. 76). Finally, two independent attempts at a unifying theory have lately been sketched out, one by Trager (1958, 1960) and another by Stankiewicz (1960).

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[15] See also *The Descent of Man*, 1871. Darwin's observations were based, in the main, on domestic cats and dogs, and man. Margaret Mead, in her preface to a 1955 edition of the former book, stresses the relevance of Darwin's work to "the new science of kinesics. . . ." On Darwin and linguistics, see Schleicher (1873) and four recent discussions of the evolution of language as part of the evolution of communication: Greenberg (1957, Ch. 5), Brosnahan (1960), Critchley (1960), and Birdwhistell (1960).

[16] Jakobson, Fant, and Halle (1962, p. 15) pair "expressive features" with "neutral, unemotional" features, where the former are said to present "a grading gamut" in contrast to the dichotomous scale of the distinctive features.

[17] For a discussion of this notion and citation of the literature, see Sebeok (1959).

A consistent typology of the several kinds of features, it is generally agreed among linguists, is one of the most urgent tasks to be accomplished. A reliable description and classification of the features across species would be no less useful. We already know that some subhuman communicative systems not only are diagnostic of the species but also allow for enough individual variation to yield, as in chaffinches, "very strange songs," or idiolects: the song of the chaffinches is so organized, we are told, "that individual birds are recognizable, even by human beings, by their personal signature tune," as a result of learning during the early life of a bird. Furthermore, a group of birds will, by mutual imitation, build into its over-all pattern a distinctive set of community traits, thus forming a dialect (Marler, 1956; Stadler, 1930; on bee dialects, see von Frisch, 1962). How such networks are woven in different species, how they operate, and of what survival value they may be are but dimly perceived at present.

Most linguists who deal with expressive or paralinguistic phenomena appreciate that the coding of the features involved may—although need not—be analog. Thus Trager (1958) writes: "These voice qualities as described seem to involve paired attributes, but the pairs of terms are more properly descriptive of extremes between which there are continua or several intermittent degrees." And Stankiewicz (1960) puts it this way: "The expressive elements are . . . in a binary relation to the neutral terms, and present a graded scale in relation to each other. Grading is not, however, a necessary characteristic of the expressive units. On the expressive level they may furthermore form binary relations to each other. . . ." Such features appear, in fact, to have but one attribute in common: they may not coincide both in form and in distribution with those features which possess distinctive, viz., cognitive function; in this sense, they are conditioned by the system, and we would therefore consider them a part of language. Graded elements may turn out to be formally identical with some distinctive elements in a given language, but then they must be distributed differently. Thus length in Hungarian is phonemic: ε ("open e"), as in *εl* "away" is opposed distinctively to *e·* (long "close e"), as in *e·l* "he lives"; but long (open) ε· (with varying degrees of duration) may be opposed to short ε only affectively: *εmber* "man" vs. ε·*mbεr* "man"! Or graded elements may differ formally, as does the vocoid in the Hungarian interjection *ɯ*, a global "gesture" no part of which recurs in that language.

THE DISCRETE VS. THE CONTINUOUS APPROACH

Are such features a part of language or are they not? Not a few linguists favor an attitude of reductionism which attempts to oppose absolute (whether or not binary) categories, said to belong to language, to phenomena which they find they cannot describe precisely in such terms and which they therefore relegate as "nonlinguistic elements of the real world," to be purged from a science of linguistics. Here is a dramatic statement of this position: "Ordinary mathematical techniques fall mostly into two classes, the continuous (e.g., the infinitesimal calculus) and the discrete or discontinuous (e.g., finite group theory). Now it will turn out that the mathematics called 'linguistics' belongs in the second class. It does not even make any compromise with continuity, as does statistics, or infinite-group theory. Linguistics is a quantum mechanics in the most extreme sense. All continuity, all possibilities of infinitesimal gradation, are shoved outside of linguistics in one direction or the other" (Joos, 1950).

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[18] Cf. also Moses (1954) and Pittenger, Hockett, and Danehy (1960). For a summary of the rapidly growing literature dealing with the reflection of psychological states in verbal behavior, see Mahl (1960, fn. on pp. 2-3).

Another linguist seems to oppose discreteness of contrast to continuity in scale as language vs. the rest of culture: "The embedding medium of linguistic messages . . . shows a continuous scale of dynamics, organized to some extent in any given culture: one may speak softly, or more loudly, or more loudly still, or anywhere in between with no theoretic limit to the fineness of gradation. But . . . in general . . . if we find continuous-scale contrasts in the vicinity of what we are sure is language, we exclude them from language (though not from culture)" (Hockett, 1955, p. 17).

The two disciplines, considered by some to be separate from linguistics, to which continuity is most often consigned are semantics at one extreme and phonetics at the other. The following quotation illustrates the former: "In some areas of lexicon, semantic structure may be so complex that it is impossible or unprofitable to approach it . . . with Aristotelian class logic and the 'same or different' pragmatic test as the principal tools. . . . Continuous scales may be introduced in place of these sharp dichotomies . . ." (Lounsbury, 1956). In the other discipline, phonetics, it is just the expressive elements of speech which are prone to be described as fluctuating phenomena beyond the reach of science. Thus one linguist writes: " . . . the rhetorical accent is subject to gradations: the length may be augmented and the intensity increased to convey overtones of awe, amazement, admiration, and many other subtle and elusive shadings in attitude. . . . Whether or not the linguist attempts to analyze and define the various types and styles of expressive accent, he must eliminate the phonetic increments introduced by such expressive factors in order to deal directly with the grammatically significant category of stress accents" (Newman, 1946). The same theme was sounded, perhaps more cautiously, in the conclusion of a monograph on American English intonation: "The most deep-seated cleft between groups of characteristics occurs between items which are organized into SYSTEMATIC contrasts and those which have merely GRADIENT differences. . . . If linguistics is to classify only language structure, then it limits itself to describing only systematic contrasts. . . . The gradient items are usually excluded from linguistics as such . . ." (Pike, 1945, p. 170; see also Bolinger, 1961). But, some sixteen years later, this same colleague wrote: "Voice quality would . . . in my view be considered linguistically relevant whether, on the one hand, unitized (i.e., 'discretely coded') in contrastive phonemes or in componential systems such as whisper versus song, or whether, on the other hand, it is socially significant but gradient (i.e., 'continuously coded' by degree) as may be rates of speed, degree of voice loudness, or general height of voice" (Pike, 1960, p. 52a).

Students of verbal behavior, including linguists animated by an awareness of psychology, are more likely to approve an expression such as "the flow of speech" as being a rather apt simile and thus tend toward the other extreme: "It will be useful to replace," a psychologist of language recently argued, "dichotomy with a continuum"; and he goes on to "speak of the relative 'criteriality' of an attribute for a category" (Brown, 1958, p. 10). A linguist and another psychologist, writing jointly, more judiciously separate the spurious continuity of segmentable speech stretches from the functional continuity of hesitation phenomena, and call for a statistical approach to complement, rather than to replace, the usual discrete one: "If we define *structure* as a list of elements and statements about the permissible relations among them it may be that the most acceptable compromise will involve reliance upon discrete assumptions to define units . . . and continuous statistical assumptions to state their rules of combination and distribution" (Maclay & Osgood, 1959).

A shift in professional opinion is reflected, finally, in this prediction by a linguist writing nine years later than the author of the first in this series of quotations: "Those factors of 'rasp, overloudness, chuckling' and the like are still usually mentioned as being outside the field of linguistics proper—more or less as intonation was outside the domain some decades ago. However, even those who place the voice qualifiers outside are nowadays, I think, placing them 'just outside.' Their role in psychiatrically applied linguistic research shows signs of being so crucial that they may before long establish a status as describable elements of a speech system" (Twaddell, 1959, p. 151).[19]

At least one prominent linguist, Sapir (1944), has not hesitated to carry out an analysis of grading, however fragmentary, on the semantic level in an important but neglected paper. He discusses and exemplifies logical, psychological, and linguistic grading in language, and then summarizes as follows: "logical grading is of the open-gamut type and may be with or without reference to an objective norm or statistical average, while psychological grading and linguistic grading tend strongly to emphasize closed-gamut grading, whether of the conjunct or disjunct type, and have difficulty in combining the notions of grading and norming into that of a normed field within which grading applies." He also takes up the role of affect and kinesthesia, and the use of polar terms, but he nowhere implies that he is outside the realm of linguistics.

It is instructive to contrast Sapir's analysis of semantic grading in language with Haldane's terse conclusion, "Animal signals grade into one another," illustrated by an example in geese (*Anser anser*), cited after Lorenz: "A group of geese produce phrases of about ten 'honks' when at rest. If moving on the ground the number diminishes as the speed increases, until flight the 'honk' is monosyllabic. Its pitch also alters" (1955, p. 392).

In logic, at least since Peirce, and in linguistics, at least since de Saussure, it has been taken for granted that the connection between a speech sign vehicle (or the signifier) and its meaning (or the signified) is arbitrary rather than iconic. According to Hockett (1959), "the contrast between arbitrary and iconic is also exemplified by digital and analog computers. An analog computer is often beautifully adapted for a narrow function and worthless for anything else. Just so, bees can talk about nectar and hive-sites; human beings can talk about anything." Now the most interesting point about the property of arbitrariness is this: that it is a logical consequence of digital structuring in the code. The connection has been demonstrated by a mathematician, Mandelbrot, who has further shown that the discrete character of linguistic units necessarily follows from the continuous nature of their substratum: if linguistic signs are discrete, Mandelbrot argues, this is just because they are, so to speak, "carried" by continuous sounds. The point of view which insists on expelling all continuous phenomena from language, furthermore, cannot allow for linguistic change, as Mandelbrot has also noted: a structural "diachronie interne" presupposes that the discreteness has not been established perfectly. Every diachronic law necessarily contradicts the rule of stability which motivates the characteristic of discreteness. This, moreover, is quite normal, since real diachronic effects appear only when the number of repetitions is extremely large and when the effect of "stability by repetition" can no longer be maintained (1954; see also Martinet, 1955).

A series of fascinating experiments with the reactions of American and French crows and gulls to recorded communication signals, tested reciprocally, has led to the hypothesis that a change in the acoustical behavior of deviant individuals may also be the first step in the evolution of a new species among animals which use sound for sexual signalling; assuming that such patterns are genetically determined, they could result in selective mating and thereupon a separate breeding population of individuals having a similar appearance (H. Frings, M. Frings, J. Jumber, R.-G. Busnel, J. Gibian, & P. Gramet, 1958; see also Marler, 1960).

One might speculate that, from the standpoint of evolution, the function of an analog mechanism is to produce behavioral isolation leading, in due time, to other genetic changes and thus to formal diversity within the subpopulations. Digital mechanisms, on the other hand, were introduced later, when the scanning and integration of much larger quantities of information—and more exactly—acquired adaptive value.

In her Presidential address at the 1960 Annual Meeting of the American Anthropological Association, Margaret Mead singled out a number of areas where a failure to build appropriate cross-disciplinary bridges has tended to stunt our field's capacity for orderly growth. "There is one adjacent science," she pointed out, "which has developed enormously during the last three decades and now can provide us with highly variegated and well-established information about the behavior of living creatures that could be of the greatest fruitfulness for our own studies. This is the discipline called ethology in Europe and the comparative study of animal behavior in the United States. Here, the anthropologist and the ethologist, each with his wealth of detail, can communicate in the concrete terms so dear to both and no conceptual model is needed beyond some basic familiarity with biology . . ." (1961, p. 479). With unfailing perception, she has identified a hitherto neglected research opportunity of considerable promise. However, if articulate transactions between two sciences of such differing content and varied traditions are to be carried out with reasonable sophistication, a unifying theory upon which both can agree, at least as a point of departure, will be a minimal requirement.[20]

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[19] Problems in the transposition of a semicontinuous natural signal into a series of discrete elements are also discussed by Peterson (1957) and Fant (1960, Ch. 1, Sec. 12, and Ch. 3, Sec. 1).

REFERENCES

Benveniste, E. Animal communication and human language. *Diogenes*, 1952, 1, 1-7.

Birdwhistell, R. L. Implications of recent developments in communication research for evolutionary theory. In W. M. Austin (Ed.), *Report of the Ninth Annual Round Table Meeting on Linguistics and Language Studies.* Washington, D. C.: Georgetown Univ. Press, 1960. Pp. 149-155.

Bolinger, D. L. *Generality, gradience, and the all-or-none.* 's-Gravenhage: Mouton, 1961.

Brosnahan, L. F. Language and evolution. *Lingua*, 1960, 9, 225-236.

Brown, R. *Words and things.* Glencoe, Ill.: Free Press, 1958.

Bühler, K. *Sprachtheorie.* Jena: Fischer, 1934.

Cassirer, E. *An essay on man.* New Haven: Yale Univ. Press, 1944.

Cherry, C. *On human communication.* New York: Wiley, 1957.

Collias, N. E. An ecological and functional classification of animal sounds. In W. E. Lanyon & W. N. Tavolga (Eds.), *Animal sounds and communication.* Washington, D. C.: American Institute of Biological Sciences, 1960. Pp. 368-387.

Coxeter, H. S. M. *Introduction to geometry.* New York: Wiley, 1961.

Critchley, M. The evolution of man's capacity for language. In S. Tax (Ed.), *Evolution after Darwin.* Vol. 2. Chicago: Univ. of Chicago Press, 1960. Pp. 289-308.

Darwin, C. *The descent of man.* London: Appleton, 1871.

Darwin, C. *The expression of the emotions in man and animals.* London: Appleton, 1872.

de Haan, J. A. Animal language in its relation to that of man. *Biological Reviews and Biological Proceedings of the Cambridge Philosophical Society*, 1929, 4, 249-268.

DuBrul, E. L. *Evolution of the speech apparatus.* Springfield, Ill.: Charles C Thomas, 1958.

Elias, P. A note on the misuse of "digital" in neurophysiology. In W. A. Rosenblith (Ed.), *Sensory communication.* Cambridge: M.I.T. Press, 1961. Pp. 794-795.

Evans, L. *Transactions of the First Conference on Group Processes.* New York: Josiah Macy, Jr., Foundation, 1955. P. 274.

Fano, R. M. *Transmission of information.* Cambridge: M.I.T. Press, 1961.

Fant, C. G. M. *Acoustic theory of speech production.* 's-Gravenhage: Mouton, 1960.

Frank, L. K. Tactile communication. *Genetic Psychol. Monogr.*, 1957, 56, 209-255.

Frank, L. K. A psychocultural approach to religion and science. *Crane Review,* 1960, 3, 19-40.

Frings, H., & Frings, M. The language of crows. *Sci. Amer.*, 1959, 201, 119-131.

Frings, H., Frings, M., Jumber, J., Busnel, R. -G., Gibian, J., & Gramet, P. Reactions of American and French species of *Corvus* and *Larus* to recorded communication signals tested reciprocally. *Ecology*, 1958, 39, 126-131.

Geldard, F. A. Some neglected possibilities of communication. *Science*, 1960, 131, 1583-1588.

Gerard, R. W. *Transactions of the Seventh Conference on Cybernetics.* New York: Josiah Macy, Jr., Foundation, 1951.

Gerard, R. W. Brains and behavior. In J. N. Spuhler (Ed.), *The evolution of man's capacity for culture.* Detroit: Wayne Univ. Press, 1959. Pp. 14-20.

Gilmer, B. v. H., & Gregg, L. W. The skin as a channel of communication. *ETC.*, 1961, 18, 199-209.

Goffman, E. *The presentation of self in everyday life.* New York: Doubleday, 1959.

Goldstein, K. *Language and language disturbances.* New York: Grune, 1948.

Greenberg, J. H. *Essays in linguistics.* Chicago: Univ. of Chicago Press, 1957.

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[20] An "Interdisciplinary Work-Conference on Paralinguistics and Kinesics" was held at Indiana University on May 17-19 of this year. A volume, based on the papers and transactions of the conference, is being edited by the author of this paper, with A. S. Hayes and M. C. Bateson. An interim report has appeared in *The Linguistic Reporter*, 1962, 4, 4; the book will be published by Mouton & Co., in 1963.

Greenberg, J. H. Language and evolution. In Betty J. Meggers (Ed.), *Evolution and anthropology: a centennial appraisal.* Washington, D. C.: Anthropological Society of Washington, 1959. Pp. 61-75.

Griffin, D. G. *Listening in the dark.* New Haven: Yale Univ. Press, 1958.

Haldane, J. B. S. Animal communication and the origin of human language. *Sci. Progress*, 1955, 43, 385-401.

Hall, E. T. *The silent language.* New York: Doubleday, 1959.

Halle, M. In defense of the number two. In E. Pulgram (Ed.), *Studies presented to Joshua Whatmough on his sixtieth birthday.* 's-Gravenhage: Mouton, 1957. Pp. 65-72.

Haskell, P. T. *Insect sounds.* Chicago: Quadrangle Books, 1961.

Hayes, F. Gestures: a working bibliography. *Southern Folklore Quart.*, 1957, 21, 218-317.

Hockett, C. F. *A manual of phonology.* Baltimore: Waverly, 1955.

Hockett, C. F. Animal "languages" and human language. In J. N. Spuhler (Ed.), *The evolution of man's capacity for culture.* Detroit: Wayne Univ. Press, 1959. Pp. 32-39.

Hockett, C. F. The origin of speech. *Sci. Amer.*, 1960, 203, 89-96. (a)

Hockett, C. F. Logical considerations in the study of animal communication. In W. E. Lanyon & W. N. Tavolga (Eds.), *Animal sounds and communication.* Washington, D. C.: American Institute of Biological Sciences, 1960. Pp. 392-430. (b)

Jakobson, R. On linguistic aspects of translation. In R. A. Brower (Ed.), *On translation.* Cambridge: Harvard Univ. Press, 1959. Pp. 232-239.

Jakobson, R. Linguistics and poetics. In T. A. Sebeok (Ed.), *Style in language.* New York: Wiley, 1960. Pp. 350-377.

Jakobson, R. Linguistics and communication theory. *Proc. of symposia in applied math.*, Amer. Math. Soc., 1961, 12, 245-252.

Jakobson, R., Fant, C. G. M., & Halle, M. *Preliminaries to speech analysis.* Cambridge: M.I.T. Press, 1952.

Jakobson, R., & Halle, M. *Fundamentals of language.* 's-Gravenhage: Mouton, 1956.

Joos, M. Description of language design. *J. acoust. soc. Amer.*, 1950, 22, 701-708.

Kainz, F. *Psychologie der sprache.* Vol. 2. Stuttgart: F. Enke, 1943.

Kellogg, W. N. *Porpoises and sonar.* Chicago: Univ. of Chicago Press, 1961.

Koehler, O. Thinking without words. *Proceedings of the 14th International Congress of Zoology (Copenhagen, 1953).* 1956. Pp. 75-88.

Kroeber, A. L. Sign and symbol in bee communications. *Proc. Natl. Acad. Sci.*, 1952, 38, 753-757.

Laziczius, G. *General linguistics.* Budapest: Magyar Tudományos Akadémia, 1942.

Lévi-Strauss, C. Leçon inaugurale, Chair d'Anthropologie Sociale, Collège de France, Paris, 1960.

Lilly, J. C. *Man and dolphin.* New York: Doubleday, 1961.

Lindauer, M. *Communication among social bees.* Cambridge: Harvard Univ. Press, 1961.

Lorenz, K. *King Solomon's ring.* New York: Crowell, 1952.

Lotz, J. Speech and language. *J. acoust. soc. Amer.*, 1950, 22, 712-717.

Lotz, J. Review. *Word,* 1951, 7, 66-67.

Lotz, J. The structure of human speech. *Trans. New York Acad. Sci.*, 1954, 2, 16, 373-384.

Lounsbury, F. G. A semantic analysis of the Pawnee kinship usage. *Language*, 1956, 32, 158-194.

Mackay, D. M. On the combination of digital and analogue computing techniques in the design of analytical engines. In *Mechanisation of thought processes,* vol. 1. London: Her Majesty's Stationery Office, 1959 [1949]. Pp. 55-65.

Maclay, H., & Osgood, C. E. Hesitation phenomena in spontaneous English speech. *Word*, 1959, 15, 19-44.

Mahl, G. F. The expression of emotions on the lexical and linguistic levels. New Haven, 1960. (mimeo)

Malinowski, B. The problem of meaning in primitive languages. Suppl. 1 in C. K. Ogden & I. A. Richards (Eds.), *The meaning of meaning.* New York: Harcourt, Brace, 1923. Pp. 296-336.

Mandelbrot, B. Structure formelle des textes et communication. *Word*, 1954, 10, 1-27.

Marler, P. The voice of the chaffinch and its function as a language. *Ibis*, 1956, 98, 231-261.

Marler, P. Specific distinctiveness in the communication signals of birds. *Behaviour*, 1957, 11, 13-39.

Marler, P. Developments in the study of animal communication. In P. R. Bell (Ed.), *Darwin's biological work—some aspects reconsidered.* Cambridge: Cambridge Univ. Press, 1959. Pp. 150-206, 329-335.

Marler, P. Bird songs and mate selection. In W. E. Lanyon & W. N. Tavolga (Eds.), *Animal sounds and communication.* Washington, D. C.: American Institute of Biological Sciences, 1960. Pp. 348-367.

Martinet, A. *Économie des changements phonétiques.* Bern: A. Francke, 1955.

Martinet, A. Substance phonique et traits distinctifs. *Bulletin de la Société de linguistique de Paris,* 1957-1958, 53, 72-85.

McQuown, N. A. Linguistic transcription and specification of psychiatric interview materials. *Psychiat.*, 1957, 20, 79-86.

Mead, Margaret. *Transactions of the First Conference on Group Processes.* New York: Josiah Macy, Jr., Foundation, 1955. P. 241. (a)

Mead, Margaret. Preface in C. Darwin, *The expression of the emotions in man and animals.* New York: Philosophical Library, 1955. (b)

Mead, Margaret. Anthropology among the sciences. *Amer. Anthropol.*, 1961, 63, 479.

Morris, C. *Signs, language and behavior.* New York: Braziller, 1946. Pp. 52-55.

Morris, D. "Typical intensity" and its relation to the problem of ritualization. *Behaviour*, 1957, 11, 1-12.

Moses, P. J. *The voice of neurosis.* New York: Grune, 1954.

Newman, S. S. On the stress system of English. *Word*, 1946, 2, 171-187.

Ogden, C. K. *Opposition.* London: Kegan Paul, 1932.

Osgood, C. E., & Sebeok, T. A. *Psycholinguistics—a survey of theory and research problems.* Baltimore: Waverly, 1954.

Penfield, W., & Roberts, L. *Speech and brain-mechanisms.* Princeton: Princeton Univ. Press, 1959.

Peterson, G. E. The discrete and the continuous in the symbolization of language. In E. Pulgram (Ed.), *Studies presented to Joshua Whatmough on his sixtieth birthday.* 's-Gravenhage: Mouton, 1957. Pp. 209-218.

Pike, K. L. *The intonation of American English.* Ann Arbor: Univ. of Michigan Press, 1945.

Pike, K. L. *Language in relation to a unified theory of the structure of human behavior.* Vol. 3. Glendale: Summer Institute of Linguistics, 1960.

Pittenger, R. E. Linguistic analysis of tone of voice in communication of affect. *Psychiat. Res. Repts.*, 1958, 8, 41-54.

Pittenger, R. E., Hockett, C. F., & Danehy, J. J. *The first five minutes.* Ithaca: Martineau, 1960.

Pittenger, R. E., & Smith, H. L., Jr. A basis for some contributions of linguistics to psychiatry. *Psychiatry*, 1957, 20, 61-78.

Plath, W. Mathematical linguistics. In C. Mohrmann, A. Sommerfelt, & J. Whatmough (Eds.), *Trends in European and American linguistics 1930-1960.* Utrecht: Spectrum, 1961. Pp. 21-57.

Révész, G. *The origin and prehistory of language.* (Trans. by J. Butler). New York: Philosophical Library, 1956.

Ruesch, J. Nonverbal language and therapy. *Psychiatry*, 1955, 18, 323-330.

Ruesch, J. *Disturbed communication.* New York: Norton, 1957.

Ruesch, J., & Kees, W. *Nonverbal communication.* Berkeley: Univ. of California Press, 1956.

Sapir, E. Speech as a personality trait. *Amer. J. Sociol.*, 1927, 32, 892-905.

Sapir, E. Grading: a study in semantics. *Philos. Sci.*, 1944, 11, 93-116.

Sauer, F. Die Entwicklung der Lautäusserungen von Ei ab schalldicht gehaltener Dorngrassmücken (*Sylvia c. communis* Latham) im Vergleich mit später isolierten und mit wildlebenden Artgenossen. *Zeitschrift für Tierforschung*, 1954, 11, 10-93.

Schleicher, A. *Die Darwin'sche theorie und die sprachwissenschaft.* Weimar: H. Böhlau, 1873.

Sebeok, T. A. Gyula Laziczius (obituary). *Word*, 1959, 15, 175-182.

Shands, H. C. *Thinking and psychotherapy: an inquiry into the processes of communication.* Cambridge: Harvard Univ. Press, 1960.

Shannon, C. E., & Weaver, W. *The mathematical theory of communication.* Urbana: Univ. of Illinois Press, 1949.

Slama-Cazacu, T. *Langage et contexte.* 's-Gravenhage: Mouton, 1961.

Sluckin, W. *Minds and machines.* Baltimore: Penguin, 1960.

Smith, H. L., Jr. An outline of metalinguistic analysis. In S. J. Castiglione (Ed.), *Report of the Third Annual Round Table Meeting on Linguistics and Language Teaching.* Washington, D. C.: Georgetown Univ. Press, 1952. Pp. 59-66.

Stadler, H. Vogeldialekt. *Alauda*, 1930, 2 (suppl.), 1-66.

Stankiewicz, E. Expressive language. In T. A. Sebeok (Ed.), *Style in language.* New York: Wiley, 1960. Pp. 96-97. (Abstract)

Thorpe, W. H. The language of birds. *Sci. Amer.*, 1956, 195, 129-138.

Thorpe, W. H. *Bird-song: the biology of vocal communication and expression in birds.* Cambridge: Cambridge Univ. Press, 1961.

Trager, G. L. Paralanguage: a first approximation. *Studies in Linguistics*, 1958, 13, 1-12.

Trager, G. L. Taos III: paralanguage. *Anthropol. Linguistics*, 1960, 2, 24-30.

Trubetzkoy, N. *Grundzüge der phonologie.* Prague: Travaux du Cercle Linguistique, 1939.

Twaddell, W. F. Linguistics plus. *Report of the Tenth Annual Round Table Meeting on Linguistics and Language Studies.* Washington, D. C.: Georgetown Univ. Press, 1959. P. 151.

von Frisch, K. *Bees, their vision, chemical senses and language.* New York: Cornell Univ. Press, 1950.

von Frisch, K. Dialects in the language of the bees. *Sci. Amer.*, 1962, 207, 78-87.

von Neumann, J. *The computer and the brain.* New Haven: Yale Univ. Press, 1958.

von Weizsäcker, C. F. Sprache als Information. In *Die Sprache.* Darmstadt: Wissenschaftliche Buchgesellschaft, 1959. Pp. 33-53.

Weinberg, M. Mechanism in neurosis. *Amer. Sci.*, 1951, 39, 74-98.

White, L. A. The symbol: the origin and basis of human behavior. *Philos. Sci.*, 1940, 7, 451-463.

Wiener, N. *The human use of human beings.* Boston: Houghton Mifflin, 1950.

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